Kongeriget Danmark

Patent application No.: PA 2003 00817

Date of filing: 02 June 2003

Applicant:
(Name and address)

Danfoss A/S
Nordborgvej 81
DK-6430 Nordborg
Danmark

Title: A pressure indicator

IPC: G 01 L 19/08

This is to certify that the attached documents are exact copies of the above mentioned patent application as originally filed.

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH
RULE 17.1(a) OR (b)

Patent- og Varemærkestyrelsen
Kongeriget Danmark

Patent- og Varemærkestyrelsen
Økonomi- og Erhvervsministeriet

06 May 2004

Bo Z. Tidemann

PATENT- OG VAREMÆRKESTYRELSEN

A PRESSURE INDICATOR

Introduction

The present invention relates to a simple and reliable indicator which can be produced cheaply in very small sizes for an optical indication of a pressure difference. In particular, the invention relates to a pressure indicator of the kind which is applicable in a feed-line for indicating flow or for indicating a flow direction of a fluid medium.

Background of the invention

Pressure is typically indicated as a relative measure using standard units, e.g. bar, psi etc. In some applications, pressure sensors are inserted in a number of feed-lines to indicate a flow direction of a fluid medium. Often, such applications require no exact measure but merely an indication of the presence of a pressure difference over an element of the feed-line, e.g. indication of a pressure difference over a pump for detection of pump activity or indication of a pressure drop over a valve for detecting the state of the valve. In general, mechanical pressure sensors transform a pressure difference into mechanical movement of a scale or a pointer for a scale. The mechanical layouts of such sensors typically include one or more small, mechanically movable elements which are joined in bearings and mounted in a chassis which is large enough to house and protect the elements. Depending on the need for accuracy and reliability, all elements are machined within narrow tolerances and, accordingly, the cost for making traditional pressure sensors is high, not least for making very small sensors, e.g. for medical applications. Moreover, due to the mechanically moving elements, the reliability of traditional sensors may easily be influenced by external conditions such as changing temperatures or rough handling.

Description of the invention

It is an object of a preferred embodiment of the present invention to provide a pressure indicator which is simple to produce even with small outer dimensions and which provides reliable indications under various external conditions. Accordingly, the present invention, in a first aspect, relates to a pressure indicator for indicating a pressure difference between a pressure P1 of a first chamber and a reference pressure, said indicator comprising a pressure chamber having a sidewall with a substantially transparent inflexible first wall part arranged at a distance from a flexible second wall part, the chamber containing an optically detectable fluid under influence of the reference pressure, characterised in that the second wall part is arranged to separate the optically detectable fluid from the first chamber and to deflect upon a pressure difference between P1 and the reference pressure, said deflection changing the distance between the first and second wall parts thereby displacing the optically detectable fluid in the pressure chamber.

Due to the deflection of the second wall part which causes a displacement of the optically detectable fluid, a pressure difference between the fluid medium and the reference pressure is detectable via the fluid.

The first wall part may preferably be a stiff plate element, e.g. made from a transparent material such as glass. The second wall part could be a very thin and flexible membrane made from silicon or rubber to deflect upon even very small pressure differences.

The pressure chamber may comprise a compressible fluid content allowing the volume of the pressure chamber to change upon the deflection of the second wall part. Preferably, however, the pressure chamber is filled with a liquid incompressible substance and the volume of the pressure chamber is kept constant. In this embodiment, the second wall member is allowed to deflect by deformation of other wall parts of the pressure chamber. In other words, the shape of the pressure chamber changes while the volume is constant. During the change in shape, the distance between the first and second wall parts changes and since the chamber is filled with an optically detectable fluid, the change in distance is optically visible by watching the "thickness" of the detectable fluid layer between the two wall parts

The reference pressure is the internal pressure of the pressure chamber which acts on the second wall part and which thus counteracts P1. The reference pressure can be formed in many ways examples of which are:

- The pressure chamber can be made to exert a certain counter force against deformation of its shape. As an example, the chamber can be made from a resilient rubber material which, during deformation of the second wall part, flexes under the exertion of a certain resistance,

- the pressure chamber may form an upwardly extending open tube comprising a liquid column of the optically detectable fluid, which column provides the reference pressure,

- the pressure chamber may be connected to a source of pressure, e.g. a compressor, e.g. via a throttling valve for adjusting the reference pressure,

- the pressure chamber may be sealed with a mixed content of a liquid optically detectable fluid and a compressible gas,

- the pressure chamber may simply have an opening towards the external pressure, e.g. the atmospheric pressure, or

- the pressure chamber may have a third wall part of a flexible material, e.g. a very thin membrane, e.g. equal to the second wall part in size, shape and/or material and arranged to separate the pressure chamber from a second chamber holding a pressure P2. Inherently, this embodiment when combined with a pressure chamber filled with an incompressible fluid, results in counter phase movements of the second and third wall parts deflecting inwardly into the chamber or outwardly out from the chamber, respectively. Which of the surfaces deflect inwardly and which deflects outwardly depends on P1 relative to P2.

In any of the above described embodiments, the indicator can be made with means for adjusting the reference pressure, e.g. by adjusting the height if the liquid column, by adjusting a throttling valve, or by regulating the pressure P2.

In particular, the last mentioned embodiment, incorporating a third flexible wall part, allows the pressure indicator to be inserted in parallel with a pump, a valve or any other component of a feed-line wherein the intake and outlet sides of the component is connected to the first and second chambers, respectively. For use in such applications, it is of particular interest to make the second and third wall parts with equal characteristics, i.e. with same size, shape, thickness and of the same material and in particular so that application of equal pressures results in equal deflections of the second and third wall parts. In some applications, e.g. when P1 differs much from P2, the second and third wall parts could be made differently to balance partly or completely the expected differences between the two pressures, P1 and P2. As an example, the pressure indicator can be inserted in parallel with a high pressure pump which is designed to give a specific pressure difference between the intake and outlet side thereof. The pressure indicator may thus be designed with second and third wall parts which completely balance the pressure difference which the pump is supposed to provide. In this case, any mal-functioning of the pump leading to a higher or lower pressure difference can easily be detected by visual inspection of the optically detectable fluid between the first wall part and the second and third wall parts, respectively.

In order to allow easy detection of deflection of the second and the third wall parts simultaneously and furthermore to allow an easy and cheap manufacturing of the pressure indicator, the second and third wall parts may be formed in congruent planes, e.g. in one and the same wall of the pressure chamber. In order to further facilitate easy surveillance of the pressure indicator, the first wall part can be made from a transparent and preferably plane material, e.g. glass, arranged in a plane which is parallel to the planes of the second and third wall parts. The pressure indicator could be made in a three layers structure comprising two layers of glass arranged on each side of a layer of silicon. Prior to the assembling of the layers into one piece, a surface pattern forming the pressure chamber can be formed in a surface of the silicon layer while the opposite surface optionally is made with a surface pattern

forming the first and second chambers, respectively. The surface structures of the silicon layer may be formed in micro-scale e.g. by etching

After the assembling of the three layers, the pressure chamber is filled with the optically detectable fluid through a small hole and depending upon the principle for providing the reference pressure, the small hole may be sealed hermetically afterwards. The optically detectable fluid may preferably be a light absorbing fluid such as ink, e.g. a dark ink such as black, blue or red ink.

In medical applications, e.g. in connection with a medical dispensing apparatus, the pressure indicator may be used for detecting flow of a medical fluid. Even though the optically detectable fluid is encapsulated by the membrane, i.e. the second wall part, safety may be improved further by using an optically detectable fluid which is innoxious to living creatures and human beings.

In order to make even small deflections of the second wall part and/or the third wall part visible, the thickness of the ink layer could be kept low. Accordingly, the distance between the first and the second wall parts may be chosen in the range of 5-100 µm. when the pressure difference is zero.

In a simple and reliable embodiment, the first wall part is inspected visually either by electrical detection means or simply by an operator looking at the outer surface of the first wall part. If the reflectivity of the surface or the colour of the surface changes, pressure change is indicated between the pressures of the pressure chamber and the first chamber, respectively. Analogously, if a third wall part and a second chamber exist, change between the reflectivity or between colour of areas above the second and third wall parts, respectively, indicates pressure changes between the first and second chambers respectively. In any case, if the indicator is inspected visually, it is required that the first wall part comprises a window which is permeable to visible light. The window should be placed above the second wall part, and with regards to embodiments of the invention which incorporate a third flexible wall part and a second chamber, the window should extend to cover also the third wall part or an additional window should be provided. The second and optionally third wall part(s) need not necessarily be transparent but could be made in a colour or reflectivity which is in contrast to the colour of reflectivity of the optically detectable fluid.

In order more easily to detect the displacement of the optically detectable fluid from the areas between the first wall part and the second wall part and optionally between the first wall part and the third wall part, the pressure indicator may have second and/or third wall parts which is/are substantially transparent, and optionally, a light source, e.g. an LED could be arranged on one side of the pressure chamber for projecting a beam of light through the second and/or the third wall part, through the optically detectable fluid and through the first wall member. In that way, it is easy to

detect the distance between the wall parts by detecting the absorption of light through the pressure chamber.

In a preferred embodiment, an array of indicators according to the previous description is formed in a three layer structure comprising two glass layers arranged on each side of silicon layer. The silicon layer can be produced efficiently by use of etching and after assembling of three layers forming a large number of pressure indicators, the three layer structure may be split into units comprising a number of pressure indicators selected for a specific application.

Detailed description of the invention

In the following, a preferred embodiment of the invention will be described in further details with reference to the drawing in which:

Fig. 1 shows a cross-sectional view of an optical pressure indicator according to the present invention,

Fig. 2 shows a preferred embodiment of a pressure indicator wherein pressure difference is detected via two flexible wall parts,

Fig. 3 shows a top view of the pressure indicator of Fig. 2,

Fig. 4 shows a top view of a pressure indicator with two indication windows for the reference fluid and one, centrally located window for the fluid medium,

Fig. 5 shows an array of pressure indicators, and

Fig. 6 shows an electrical sensor device arranged to detect colour or light intensity variations of the pressure indicator according to the invention.

Referring to Fig. 1, the pressure indicator for detecting a pressure difference between a fluid medium and a reference pressure comprises a pressure chamber 1 having a first wall part 2 and a second wall part 3. The first wall part is transparent and could be made from a glass plate. The second wall part 3 is a flexible membrane formed by etching a part of a silicon plate 4 away. A first chamber 5 is separated from the pressure chamber via the flexible second wall part 3. Via the inflow and outflow channels 7, 8, the first chamber is in fluid communication with the fluid medium in question. The channels are formed in the plate 6, e.g. by drilling. Due to the arrangement of the flexible membrane between the pressure chamber and the first chamber, the membrane can be deflected either inwardly into the pressure chamber or outwardly out from the pressure chamber by a pressure difference between the internal pressure of the pressure chamber and the external pressure of the fluid medium in the first chamber. Due to the deflection, the distance between the glass

plate 2 and the membrane 3 changes, and since the pressure chamber is filled with an optically detectable fluid such as a coloured liquid, e.g. ink, the change in the distance is optically detectable by detecting changes in absorption of light passing through the pressure chamber or by detecting a colour intensity of the fluid contained in the pressure chamber. In order to enable more easy detection of the changes in absorption of light or colour intensity, the pressure indicator can be made from layers of at least substantially transparent materials, e.g. a first layer forming the first wall part 2 made of glass, a second layer forming the second wall part 3 made as a very thin and thus partly transparent silicon membrane and a third layer 6 which could be made of glass, polyester, polycarbonate, polyacrylate, polymethacrylate etc. In order more easily to detect the colour intensity or absorption of light, a light source, e.g. an LED (light emitting diode), 9 can be fastened below the third layer to transmit light through the pressure chamber.

A preferred embodiment of a pressure indicator allowing an easier detection of pressure changes between a fluid medium and a reference fluid medium is disclosed in Fig. 2. In the pressure indicator shown in Fig. 2, the pressure chamber 1 is elongated with the part 21, which part comprises a third wall part 23 in the form of a flexible membrane. A second chamber 25 containing a reference fluid under a reference pressure is arranged below the third wall part. The second chamber is in fluid communication with a reference fluid storage via the channels 27, 28. The light sources 9, 29 are optional. The filler hole 22 is provided merely for filling up the pressure chamber with the optically detectable fluid during making of the pressure indicator and may be sealed hermetically thereafter. When the filler hole is sealed, the pressure chamber is no longer in fluid communication with the surroundings. In this state, a pressure difference between the fluid media contained in the first and second chambers 5, 25, respectively, will cause deflections of the second and third wall parts in opposite directions inwardly into the pressure chamber or outwardly from the pressure chamber. As a result of the deflection, a difference between the colour and/or the light absorption may be inspected through the glass plate of the first wall part 2 above the second and third wall parts, respectively.

In Fig. 3 a pressure indicator of the kind disclosed in Fig. 2 is shown in a top view. The pressure chamber is filled with an optically detectable fluid in the form of a black ink. In the disclosed state, the pressure of the fluid medium which influences the second wall part (numeral 3 in Figs. 1 and 2) is larger than the pressure of the reference fluid medium which influences the third wall part (numeral 23 in Fig. 2). Accordingly, the distance between the first wall part, i.e. the glass plate which covers the pressure chamber, and the second wall part is shorter than the corresponding distance between the first wall part and the third wall part. As it can be seen, the result is a light spot formed above the second wall part and a dark spot formed above the third wall part. The glass plate forming the first wall part (numeral 2 in Fig. 1) has a masked-off area 31 so that the black ink can merely be seen in the two well defined windows 32, 33 inside the masked-off area.

Fig. 4 shows a pressure indicator corresponding to the indicator shown in Fig. 3, wherein an array of 3 pressure indicators having 3 pressure chambers formed side-by-side in a single block having a three-layered structure, namely two glass layers 44, 45 on each side of a silicon layer 46. Each of the pressure chambers has first compartments 41, 42, 43 and second compartments 47, 48 and 49, the first compartments being in fluid communication with the second compartments via connecting channels 50, 51 and 52. The fluid and reference fluid media pressures are provided to the first and second chambers through the feeding channels 53, 54, 55 and 56, 57, 58, respectively. The feeding channels of one chamber, e.g. the feeding channels 53 and 56 can be connected on each side of a component of a fluid feed-line, e.g. on each side of a fluid pump, a throttle or similar. Via the pressure indicator, a user of the feed-line can validate whether the component in question lowers or raises the pressure of the feed-line, i.e. whether a pump, a throttle or similar component is activated. The arrangement of more pressure chambers side-by-side allows a user more easily to get an overview of a plurality of components of the feed-line. Fig 5 shows a top view of the pressure indicator of Fig. 4 wherein the pressure at the feed-channel 53 is lower than the pressure at the feed-channel 56 and wherein the pressure at the feed-channel 55 is lower than the pressure at the feed-channels 58. This leads to a thick layer of optically detectable fluid in the first compartments 41 and 43 which hereby appear dark and to a thin layer of optically detectable fluid in the first compartment 42 which hereby appears light.

A simple way of implementing the pressure indicator is simply by visually inspecting the outer surface of the first wall part to detect changes in reflectivity or colour of light reflected from the second and optionally third wall part(s). In Fig. 6 a pressure indicator with an electrical sensor is disclosed. The sensor comprises a transmitter 61 and a receiver 62. The transmitter transmits a signal 63, e.g. an electromagnetic signal, e.g. light onto the window 64 of the indicator. Depending upon the deflection of the membrane and thus upon the displacement of the optically detectable fluid, more or less of the transmitted signal is absorbed whereby the received signal, i.e. the signal which has been reflected by the surface of the membrane, is representative of the pressure difference between the pressure of the fluid medium and the reference pressure. In an alternative embodiment, the transmitter is arranged on an opposite side of the pressure indicator to transmit the signal through the pressure chamber.

CLAIMS

1. A pressure indicator for indicating a pressure difference between a pressure P1 of a first chamber and a reference pressure, said indicator comprising a pressure chamber having a sidewall with a substantially transparent inflexible first wall part arranged at a distance from a flexible second wall part, the chamber containing an optically detectable fluid under influence of the reference pressure, characterised in that the second wall part is arranged to separate the optically detectable fluid from the first chamber and to deflect upon a pressure difference between P1 and the reference pressure, said deflection changing the distance between the first and second wall parts thereby displacing the optically detectable fluid in the pressure chamber.

2. An indicator according to claim 1, wherein the deflection of the second wall part changes the volume of the chamber.

3. An indicator according to any of claims 1 or 2, wherein the reference pressure is adjustable.

4. An indicator according to any of the preceding claims, further comprising a flexible third wall part separating the pressure chamber from a second chamber, the second chamber holding a pressure P2.

5. An indicator according to claim 4, wherein the second and third wall parts have equal surface areas towards the first and second chambers, respectively.

6. An indicator according to claim 5, wherein the second and third wall parts have equal stiffness.

7. An indicator according to claims 4-6, wherein the second and third wall parts are arranged in congruent planes.

8. An indicator according to claim 7, wherein first wall part is arranged in a plane which is parallel to the planes of the second and third wall parts.

9. An indicator according to any of the preceding claims, wherein the reference pressure is at least partly defined by a gas/atmospheric pressure external to the chamber.

10. An indicator according to any of the preceding claims, wherein the first wall part is made from glass.

11. An indicator according to any of the preceding claims, wherein the second wall part is made from silicon.

12. An indicator according to any of the preceding claims, wherein the optically detectable fluid is a light absorbing fluid.

13. An indicator according to claim 12, wherein the light absorbing fluid is a coloured liquid.

14. An indicator according to any of the preceding claims, wherein the optically detectable fluid is a fluid which is innoxious to living creatures and human beings.

15. An indicator according to any of the preceding claims, wherein the distance between the first and the second wall parts is in the range of 5-100 µm. when the pressure difference is zero.

16. An indicator according to any of claims 4-15, wherein the distance between the first and the third wall parts is in the range of 5-100 µm. when the pressure difference is zero.

17. An indicator according to any of the preceding claims, wherein the second wall part is substantially transparent.

18. An indicator according to any of the preceding claims, wherein the third wall part is substantially transparent.

19. An indicator according to any of claims 16-18, further comprising illuminating means for projecting light from an outer side surface of the second wall part, through the second or third wall part, through the chamber and out of the chamber through the first wall part.

20. An indicator according to any of the preceding claims, having a stacked configuration comprising a first layer made of glass, a second layer made of silicon and a third layer made of glass, the first and third layers having substantially plane surfaces towards the second layer and the second layer having a first surface structure towards the first layer and a second surface structure towards the third layer, wherein the first surface structure forms the pressure chamber and the second surface structure forms the first chamber.

21. An indicator according to claim 20, wherein the second wall part is formed integrally in the second layer.

22. An indicator according to claim 21, wherein at least the first surface structure is formed by etching.

23. An array of indicators according to any of the preceding claims and formed in a three layer structure comprising two glass layers arranged on each side of silicon layer.

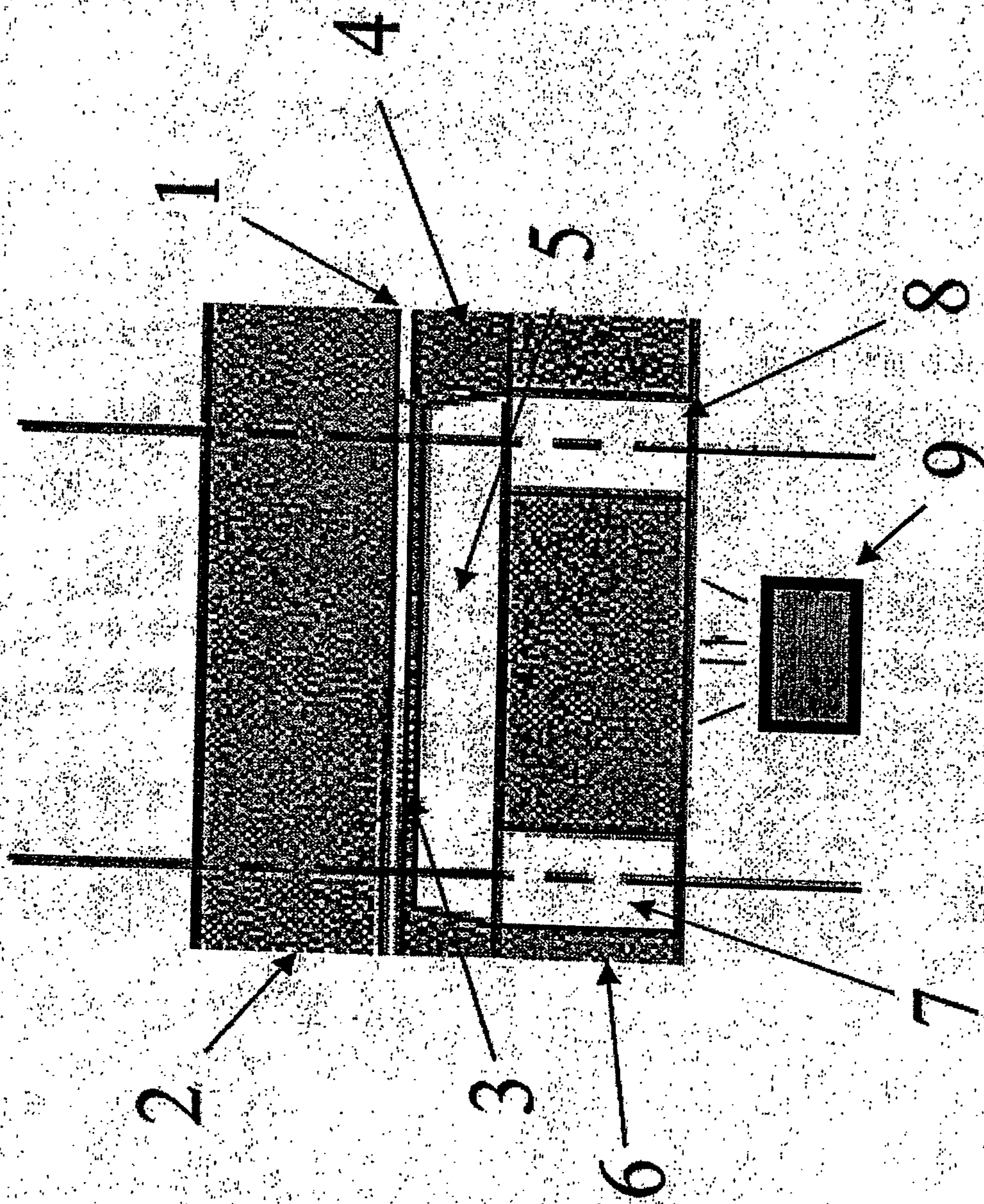

Fig. 1

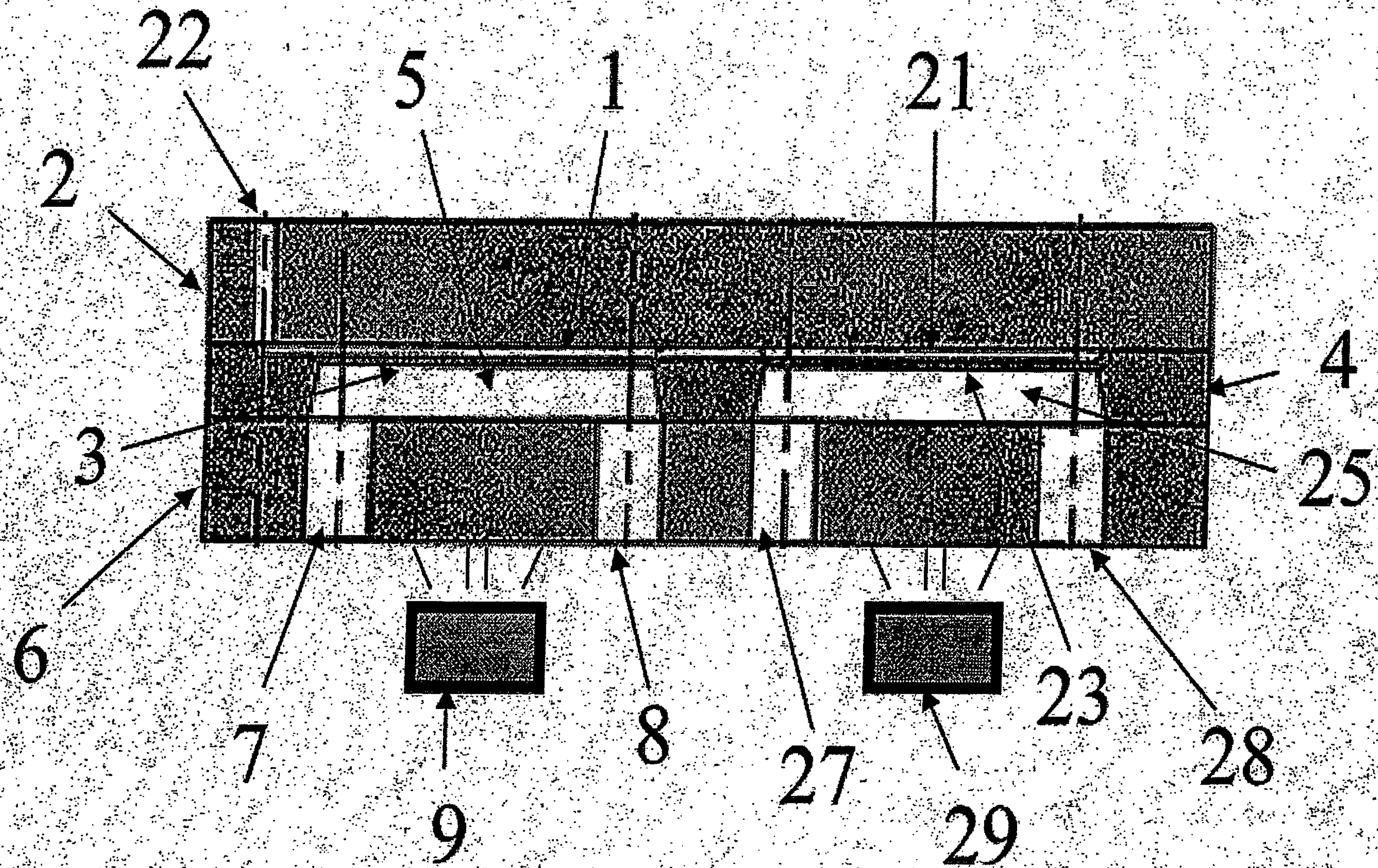

Fig. 2

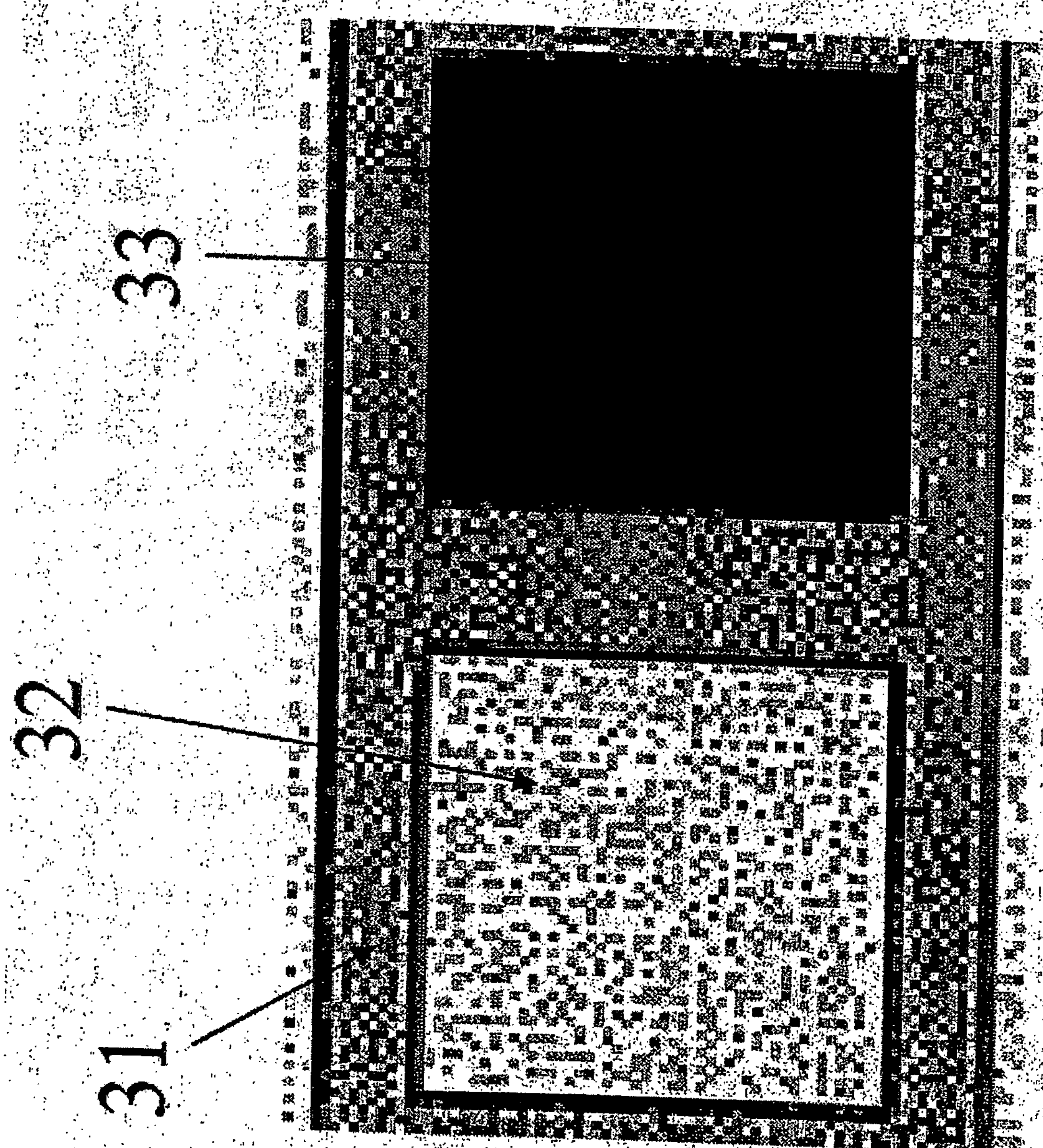

Fig. 3

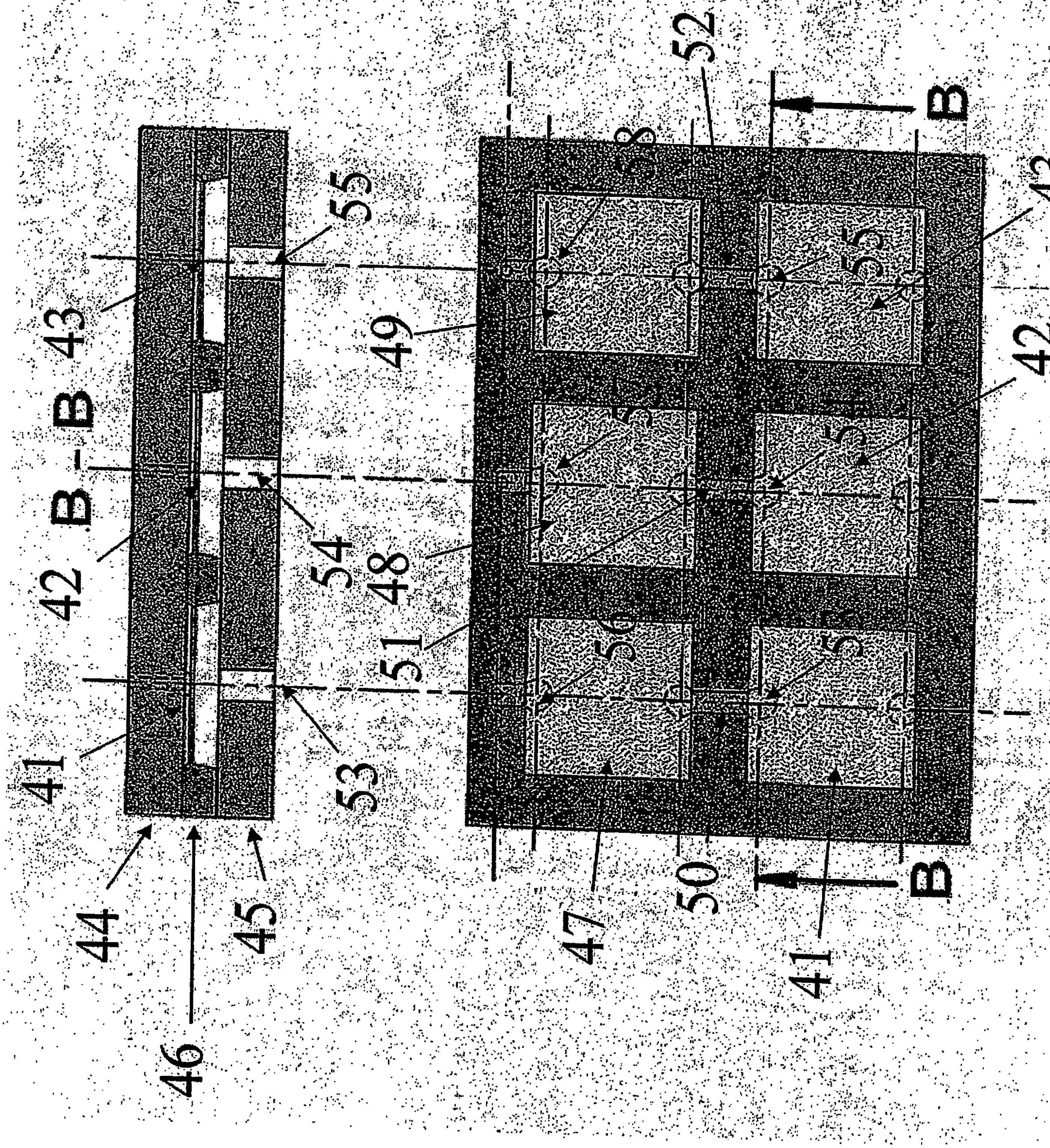

Fig. 4

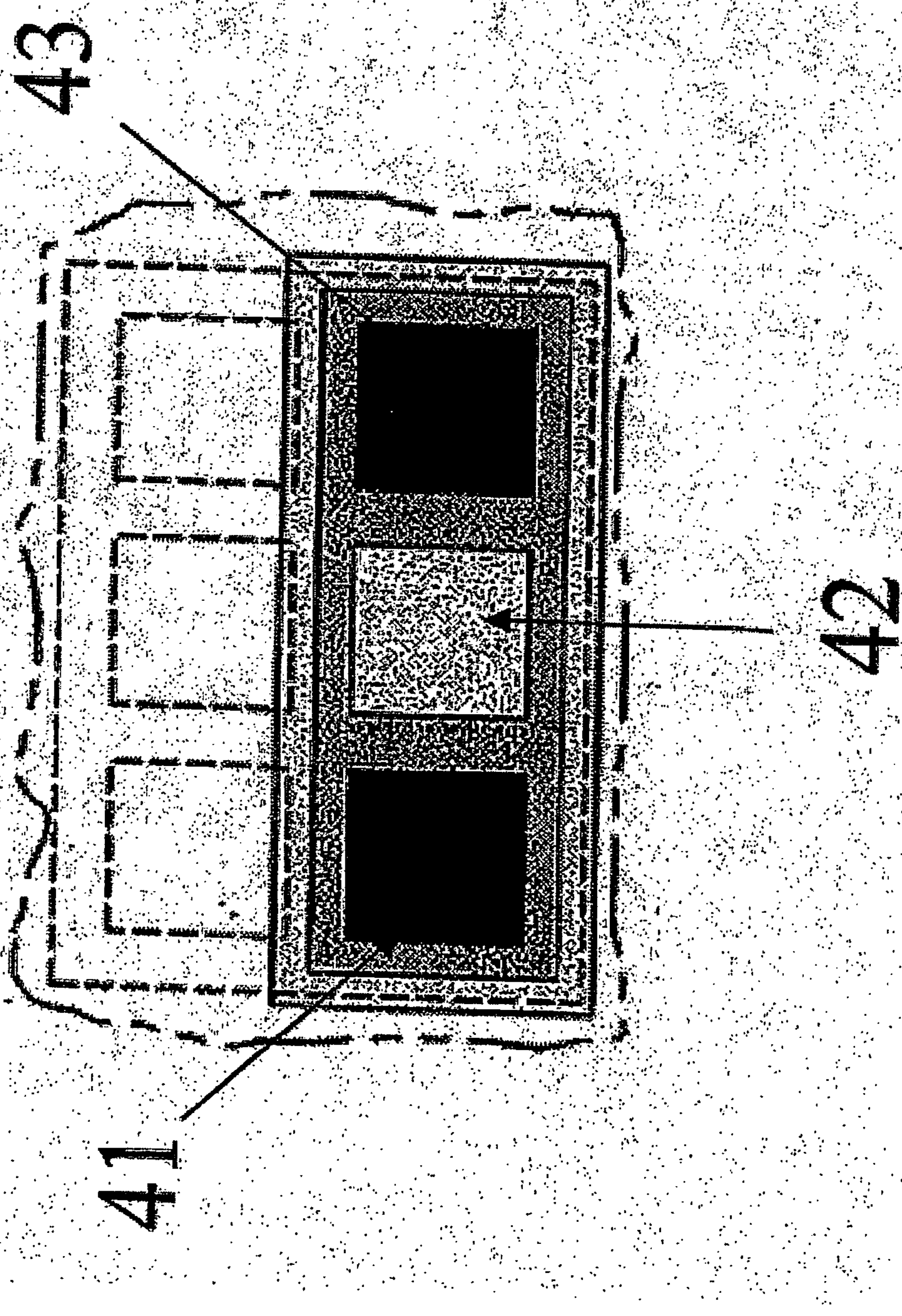

Fig. 5

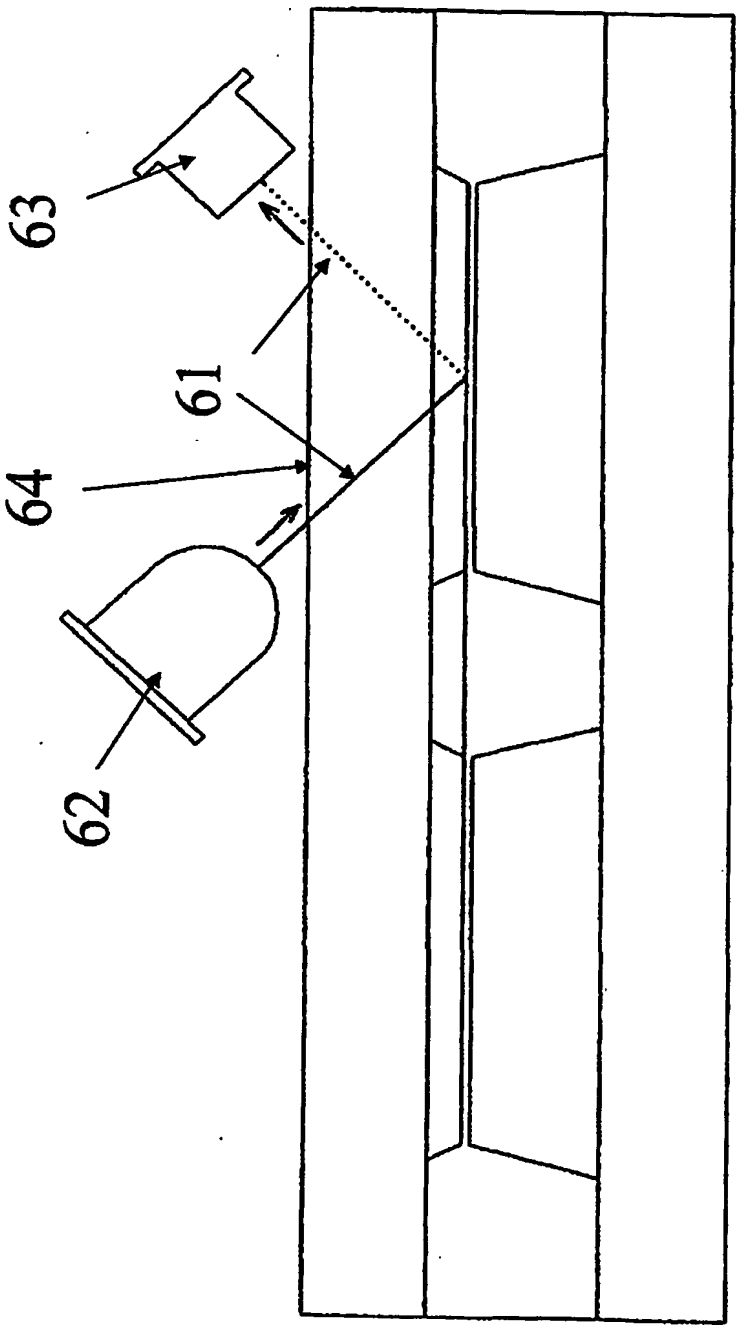

Fig. 6